AD 39241

UNCLASSIFIED

FIRST INTERIM DEVELOPMENT REPORT

Capacitors, High KVA Transmitting Types, Glass Dielectric

1 January - 31 March, 1953

Contract No. NObsr-57558

Corning Glass Works Corning, N. Y.

UNCLASSIFIED

Classification cancelled
Executive Order 10501 issued 5 November

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INTERIM DEVELOPMENT REPORT

for

CAPACITORS, HIGH KVA TRANSMITTING TYPES,

GLASS DIELECTRIC

This report covers the period January 1 to March 31, 1953.

CORNING GLASS WORKS
CORNING, NEW YORK

Navy Department Bureau of Ships Electronics Divisions

Contract NObsr-57558 June 23, 1952

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ABSTRACT

This first quarterly report contains a description of the work under Contract NObsr-55758 for high KVA transmitting types of glass capacitors, case sizes 75 through 95. A critical examination is made of the existing requirements for mica capacitors of these sizes, and their interrelation. The background of previous and current work and the results obtained pertinent to this contract is described, including Corning patents and patent applications on the capacitors and the components. Information applicable to this work which has been obtained under our present Contract DA36-039-sc-15509 for medium power capacitors is reviewed, and possible further work discussed. Work finished so far and a schedule for future work is presented in chart form, and the program for the next reporting interval is briefly outlined.

CAPACITORS, HIGH KVA TRANSMITTING TYPES, GLASS DIELECTRIC

PURPOSE

The purpose of this contract is the development of design and of manufacturing procedures for transmitting types of capacitors with glass as a dielectric. A sufficient number (25) of capacitors for test of each of 7 specific ratings will be made on the straight-run production facilities to be set up for the capacitors whose design is to be determined, and will be supplied to the Bureau of Ships for evaluation. These represent the largest capacitance rating (10,000 or 100,000 mmfd) in each of the five case sizes 75 to 95; plus the lowest (100 mmfd) and an intermediate capacitance (1800 mmfd) in the largest case size. The capacitors are specifically intended as mica replacement capacitors, and will, wherever possible, meet or exceed the requirements as outlined in the Military Specification JAN-C-5 already in existence for mica capacitors. The purpose and requirements are clearly defined in the Specification, Ships-C-695, 14 April 1952, covering this contract. Portions of this specification which are pertinent to an understanding of the aims and requirements of this work are reproduced here, for ready reference. Of interest also is the concurrent contract DA36-039-sc-15509 for development of medium power capacitors. Much of the information gained in this research is directly applicable to NObsr-57558, and will be reviewed below.

COPY

SHIPS-C-695
14 April 1952

BUREAU OF SHIPS CONTRACT SPECIFICATION

CAPACITORS, HIGH KVA TRANSMITTING TYPES, GLASS DIELECTRIC

This specification is for use only with Bureau of Ships Contract NObsr-57558. (Work Order No. 800-26278).

I. SCOPE

1.1 This specification is to cover, under the conservation of material program, the design and production techniques of high KVA transmitting types of capacitors using a glass film in place of mica as the dielectric material.

3. REQUIREMENTS.

3.1 Reliability.-Reliable performance shall be maintained under conditions of intermittent or continuous operation upon exposure to the adverse conditions normally encountered in the Naval service as generally specified in Specification 16E4. All items or parts entering into the construction of the capacitor shall be capable of operating in the temperature and humidity ranges as specified in Specification JAN-C-5.

3.2 Material.-The selection and application of materials shall be governed by the best standards and practices, and shall be suitable for Naval application in electronic equipment.

3.3 General.-The capacitors shall meet the electrical and environmental requirements of Specification JAN-C-5, except as otherwise specified herein.

3.4 The requirements of this specification shall be considered minimum requirements. The contractor shall examine possible improvements over and above those outlined herein. Approval of the Bureau of Ships shall be obtained for any deviations from the provisions of this specification.

3.5 Construction.-The contractor shall develop design and production techniques for the construction of high KVA transmitting types of capacitors utilizing a glass film as a dielectric material. The glass capacitors shall be equal to, or better than the high KVA transmitting types (CM70 to CM95) as specified in Specification JAN-C-5.

3.6 Weight and size.-In terms of size and weight, the capacitors shall be equal to or less than the high KVA transmitting types, specified in Specification JAN-C-5.

3.7 Temperature coefficient of capacitance.-The temperature coefficient of capacitance shall be no greater than 140 PPM and the temperature coefficient shall be such as to allow, as nearly as possible, a linear change of capacitance with temperature.

3.8 The contractor shall provide production facilities for straight-run production of glass dielectric, high KVA transmitting types of capacitors.

3.8.1 The contractor shall furnish from his straight-run production facilities twenty-five capacitors for each of the following ratings:

COPY

Capacitance (uuf)	Peak working voltage (volts)	Current ratings (amperes)			
		3 mc.	1 mc.	0.3 mc	0.1 mc.
10,000	15,000	51	75	47	20
100,000	3,000	30	62	43	39
100,000	2,000	24	51	39	24
100,000	1,500	20	39	36	20
100,000	1,000	18	22	22	18
100	35,000	12	6.2	2.2	0.82
1,000	35,000	33	36	20	7.5

3.11 Workmanship.-Workmanship shall be first class in every respect.

4. SAMPLING, INSPECTION, AND TEST PROCEDURES

4.1 Inspection procedures.-The general inspection procedures shall be in accordance with General Specifications for Inspection of Material.

4.2 General.-Inspection and testing of capacitors shall be conducted in accordance with Specification JAN-C-5.

4.3 Acceptability tests.-The capacitors shall be subjected to complete and exhaustive tests to determine conformance with the requirements as specified in this specification.

4.3.1 The contractor shall maintain complete records of all data taken during acceptability tests.

4.4 Performance tests.-The capacitors shall be shipped, at the contractor's expense, to such location or locations, as the Bureau of Ships may specify, for performance tests to determine compliance with the requirements of this specification.

COPY

GENERAL FACTUAL DATA

Work on glass capacitors by Corning Glass Works during the past several years has shown that the glass capacitor will probably be adaptable as a high quality capacitor for general high voltage applications. It is expected that high voltage capacitors made with glass as a dielectric will have several operational advantages over those using mica or other dielectrics now commonly used:

1. The capacitors will have a uniform and predictable performance. All properties which are determined by the behavior of the dielectric materials will be the same for every capacitor.

2. Pre-conditioning operations on the capacitor will not be necessary and changes in its properties with life, either in storage or in operation, will be a minimum.

3. It appears likely that the capacitor can be made to be of lighter weight and perhaps to occupy less volume.

4. The sub-sections of the capacitors, made of native materials, will be adaptable to the techniques of mass production.

These high power types of capacitors are usually made of sub-sections which are arranged in series-parallel combinations for the required capacitance and voltage. For glass, these sub-sections can be made as sealed units which will be integral and self-supporting. It is possible that such units can be designed so that a relatively small number of types can be used for assembly into a large range of finished capacitors. This will markedly simplify design and manufacturing problems.

The mica Specification MIL-C-5 (JAN-C-5) to which the glass capacitors will be made to adhere, wherever possible, lists a set of requirements in terms of radiofrequency current at specified frequencies for each size. In order to analyze these requirements in a systematic manner; and to intercompare the requirements for differenct sizes, the specified current has been translated into radiofrequency voltage and radiofrequency power. These requirements are presented as Figures 1 to 10 inclusive for case sizes 75 to 95. If we assume that the power factor of the capacitor is independent of the capacitance and frequency within these ranges, as it should be, then we would expect that for a given rise in temperature of the case under equilibrium conditions, the reactive power of a capacitor should also be independent of capacitance and frequency. This is, of course, subject to a derating at very low capacitances so that the radiofrequency voltage is kept below the limits determined by the geometry of the assembly, and at high capacitances so that the radiofrequency current is kept within limits determined by electrodes and connections. An examination of Figures 1 to 10 shows that the requirements as set up for mica capacitors are dependent not only on capacitance, but on frequency, and differently for different case sizes. The curves show that in general the radiofrequency power is greater at the lower of the specified 4 frequencies, and is usually greatest at 0.3 megacycles, especially through the middle ranges of capacitance.

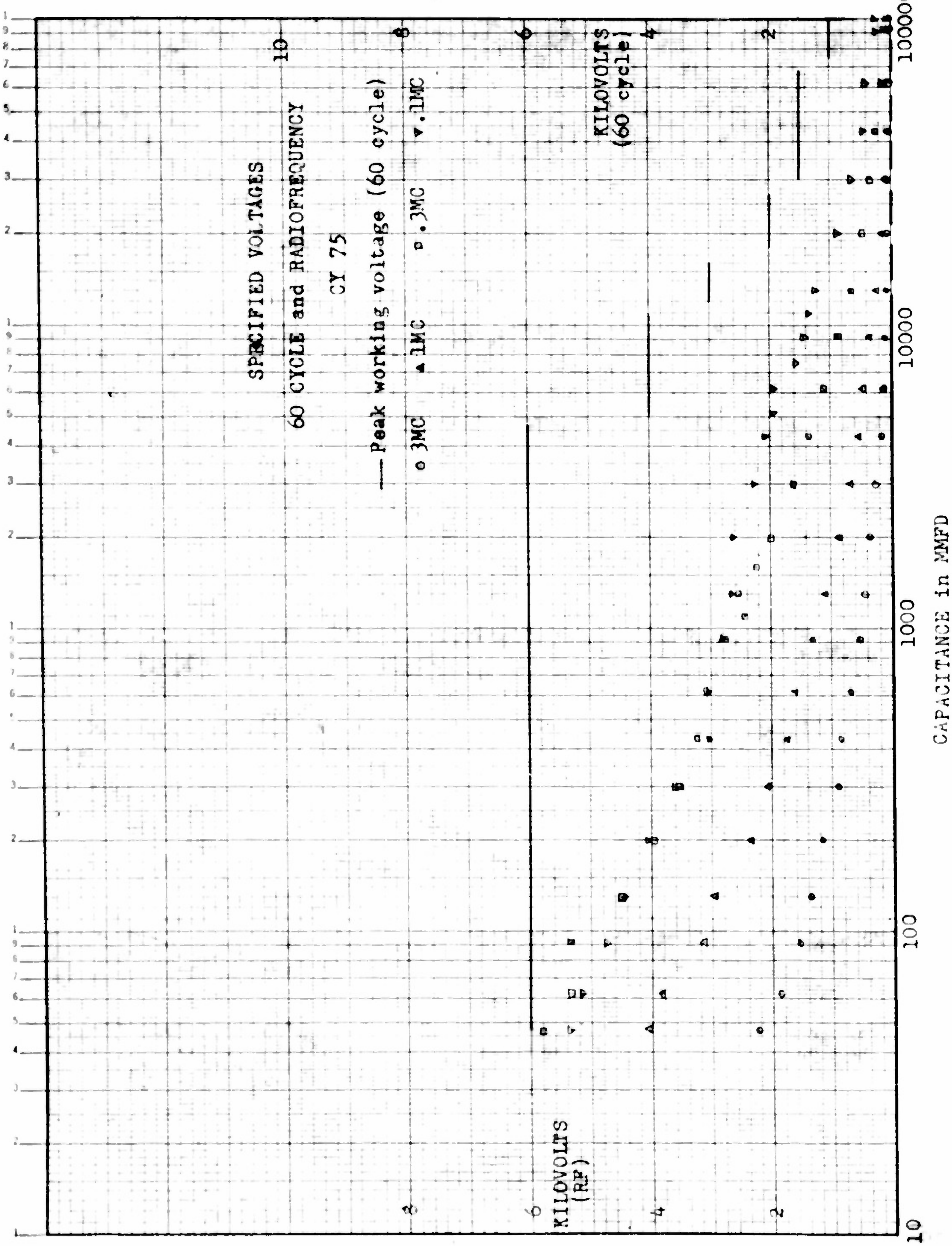

SPECIFIED VOLTAGES
60 CYCLE and RADIOFREQUENCY
CY 75
Peak working voltage (60 cycle)
3MC
1MC
.3MC
.1MC
KILOVOLTS (60 cycle)
KILOVOLTS (RF)
CAPACITANCE in MMFD
10
100
1000
10000
100000
2
4
6
8
10

FIGURE 1

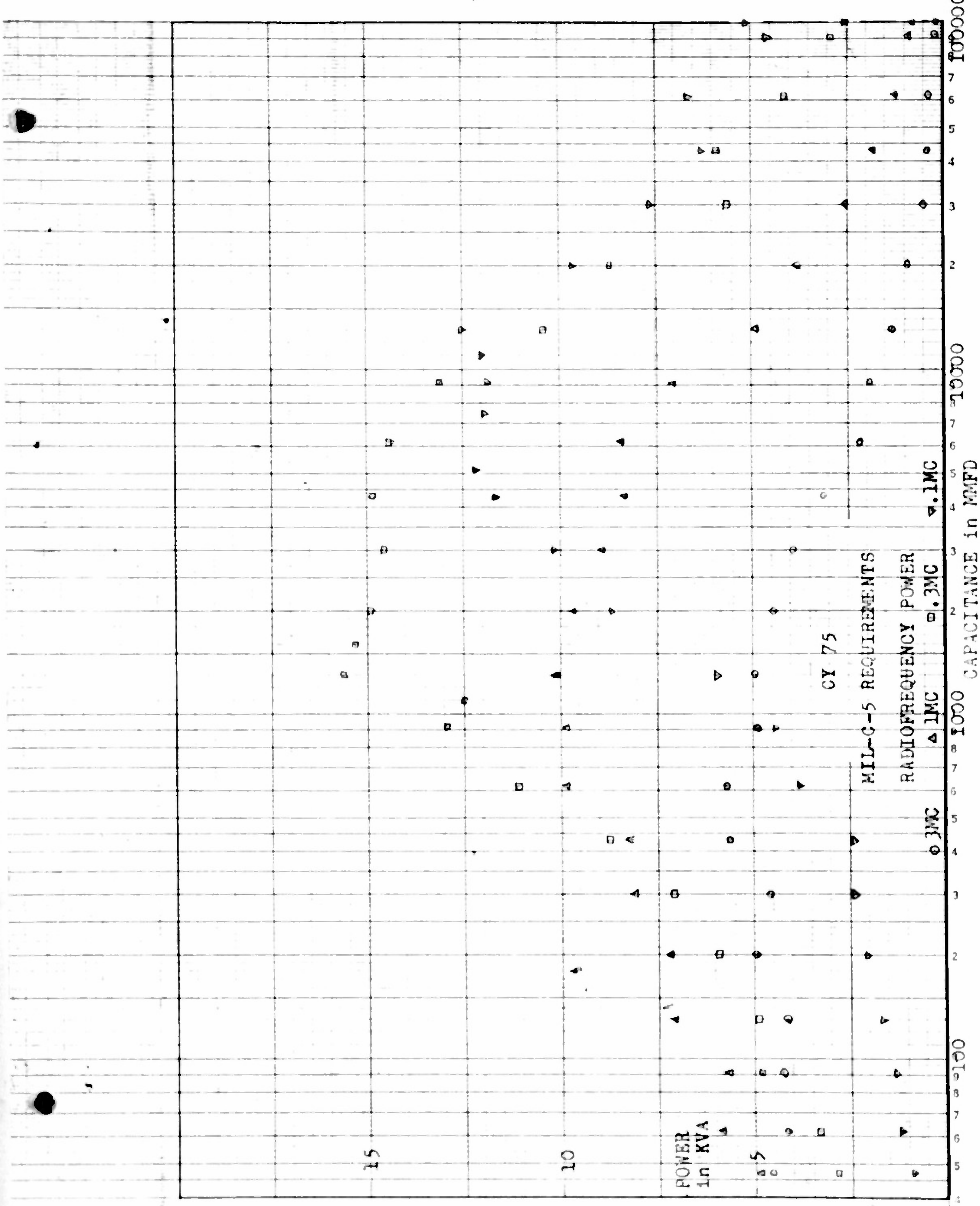

CAPACITANCE in MMFD
MIL-C-5 REQUIREMENTS
RADIOFREQUENCY POWER
CY 75
POWER in KVA
3MC
1MC
.3MC
.1MC
15
10
5
100
1000
10000
100000

FIGURE 2

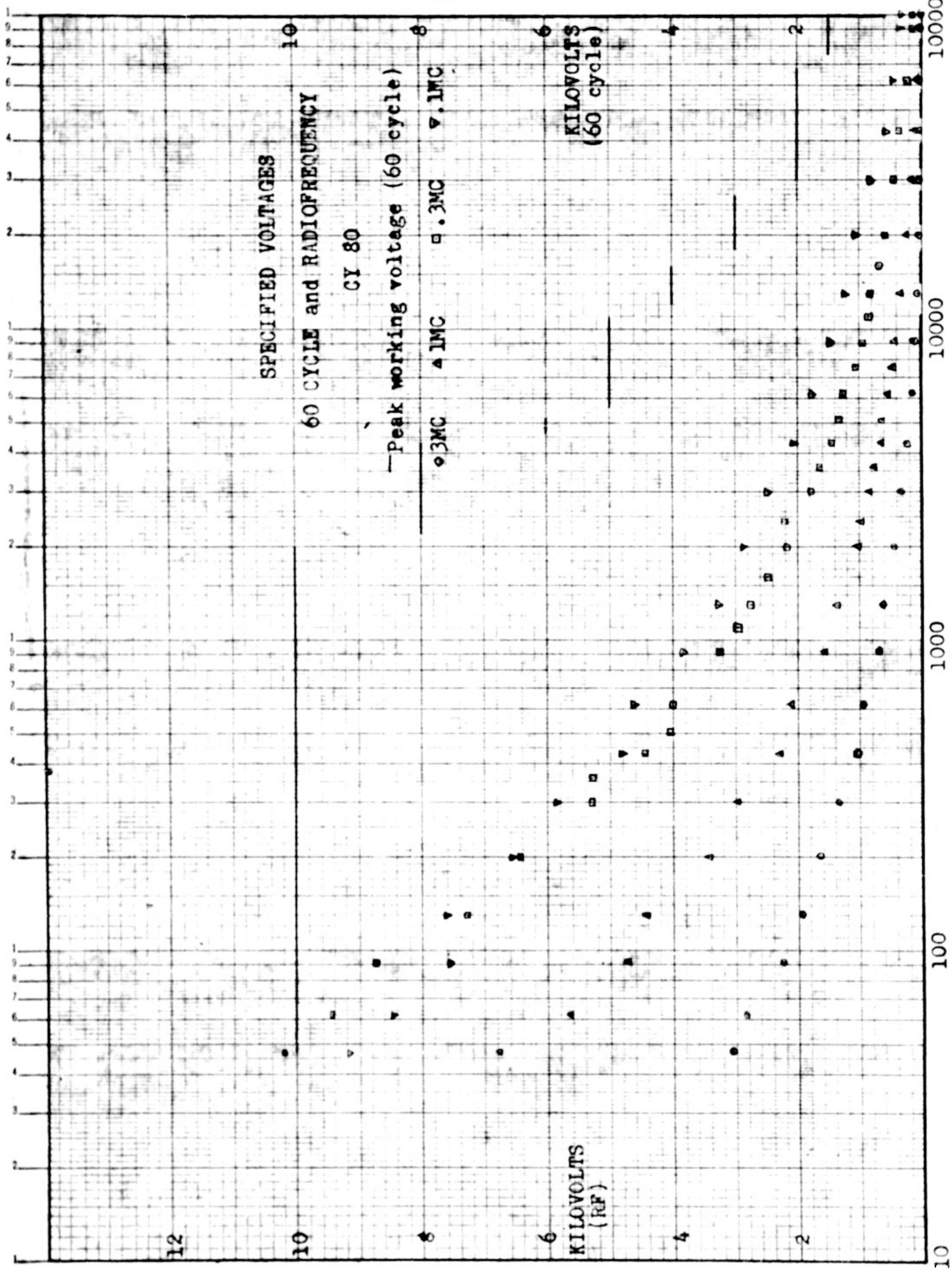

SPECIFIED VOLTAGES
60 CYCLE and RADIOFREQUENCY
CY 80
—Peak working voltage (60 cycle)
○3MC ▲1MC □.3MC ▼.1MC
KILOVOLTS (60 cycle)
KILOVOLTS (RF)
CAPACITANCE in MMFD

FIGURE 3

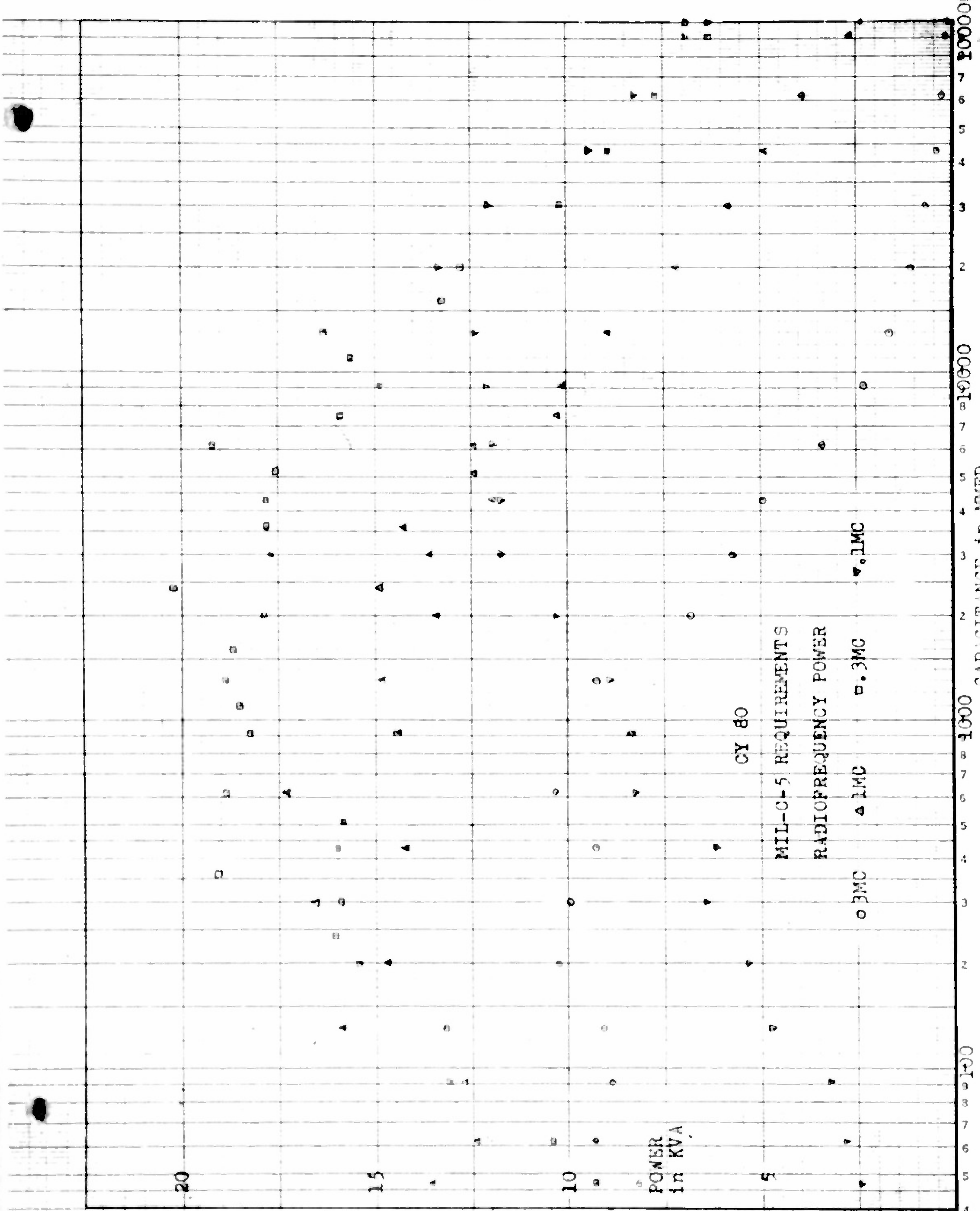

MIL-C-5 REQUIREMENTS
RADIOFREQUENCY POWER
CY 80
○ 3MC
△ 1MC
□ .3MC
▼ .1MC
POWER in KVA
CAPACITANCE in MMFD
20
15
10
5

FIGURE 4

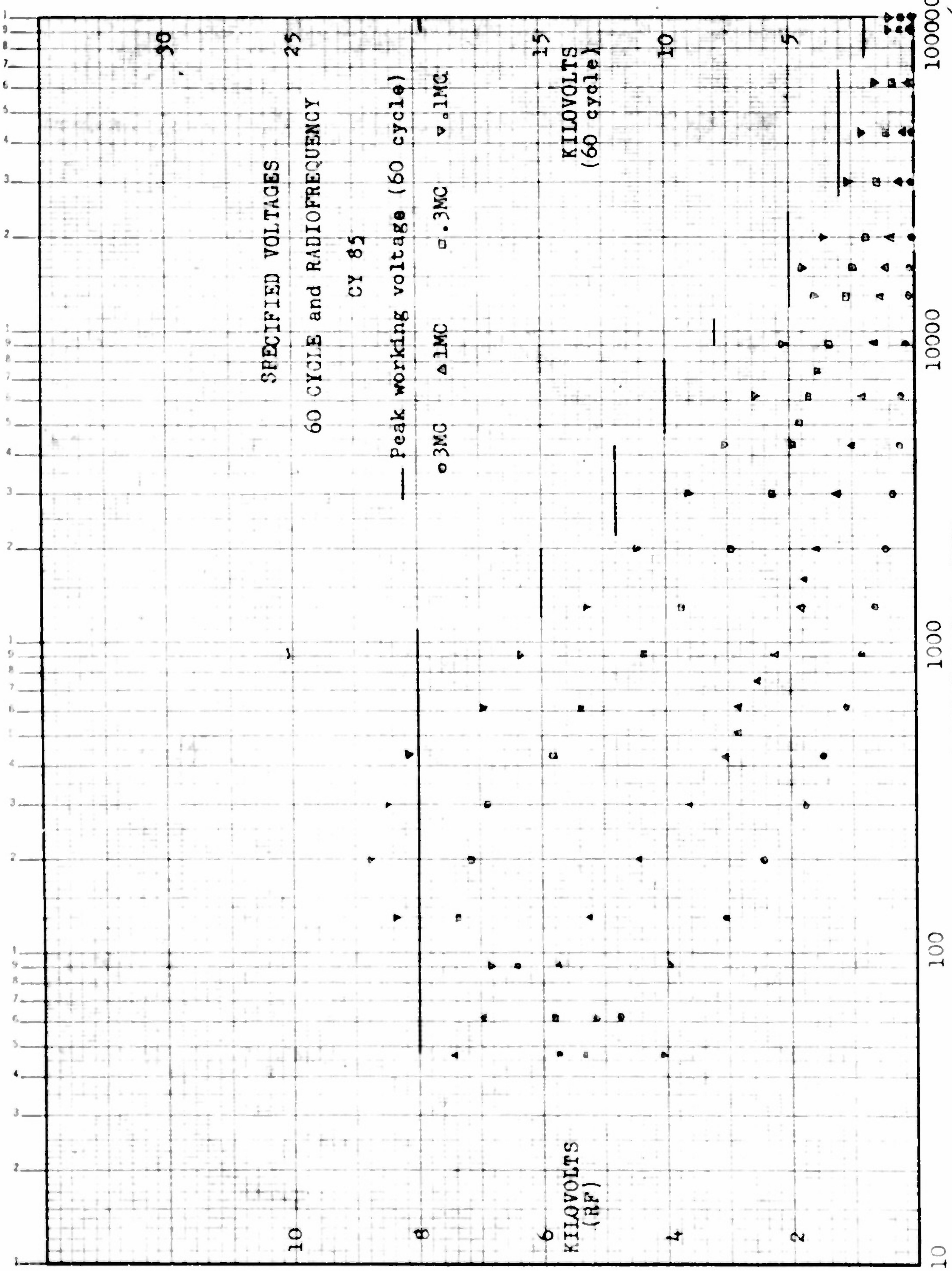

SPECIFIED VOLTAGES
60 CYCLE and RADIOFREQUENCY
CY 85
Peak working voltage (60 cycle)
3MC
1MC
.3MC
.1MC
KILOVOLTS (60 cycle)
KILOVOLTS (RF)
CAPACITANCE in MMFD
30
25
20
15
10
5
10
8
6
4
2
10
100
1000
10000
100000

FIGURE 5

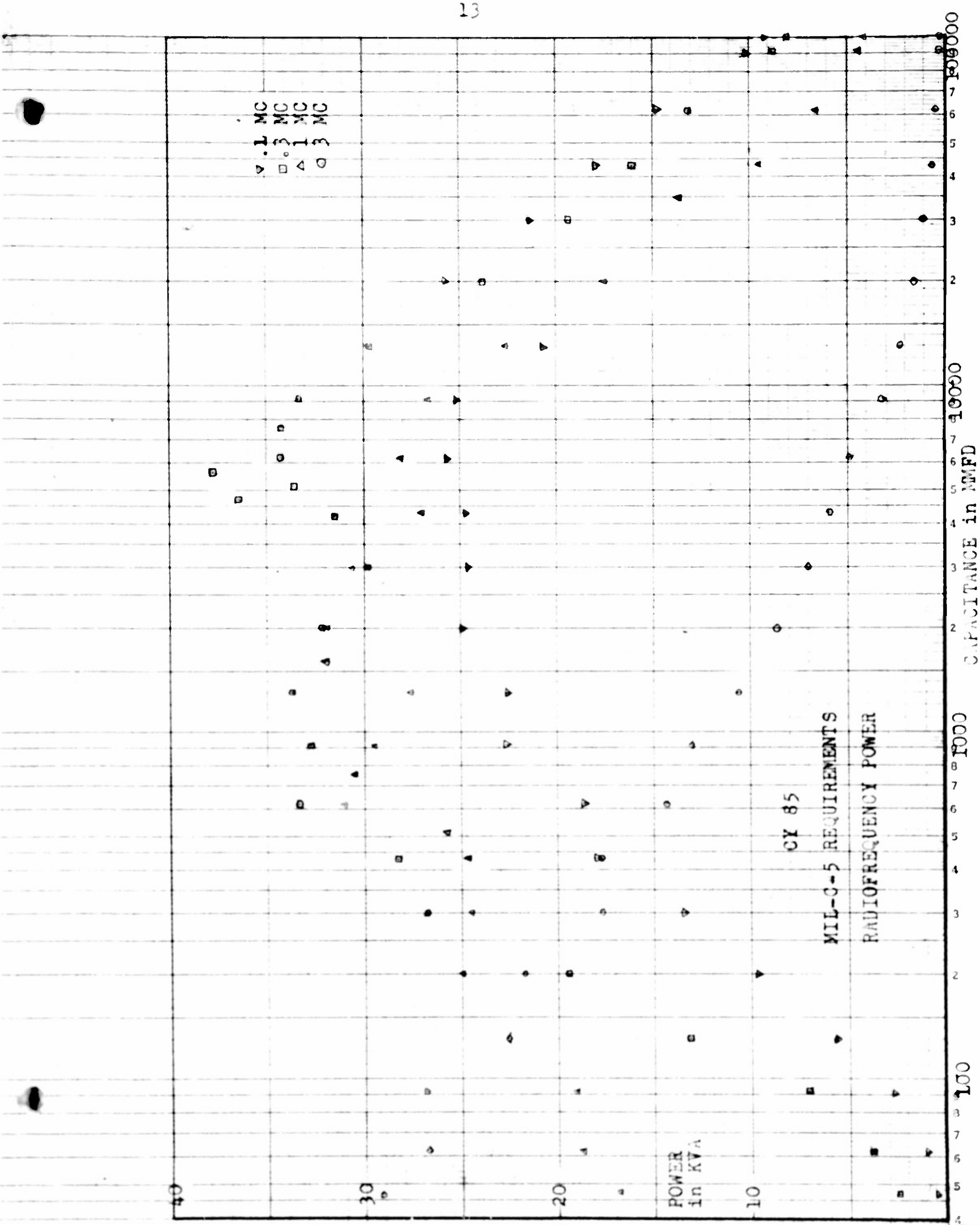

∇ .1 MC
□ .3 MC
△ 1 MC
○ 3 MC
CY 85
MIL-C-5 REQUIREMENTS
RADIOFREQUENCY POWER
POWER in KVA
40
30
20
10
CAPACITANCE in MMFD
100
1000
10000
100000

FIGURE 6

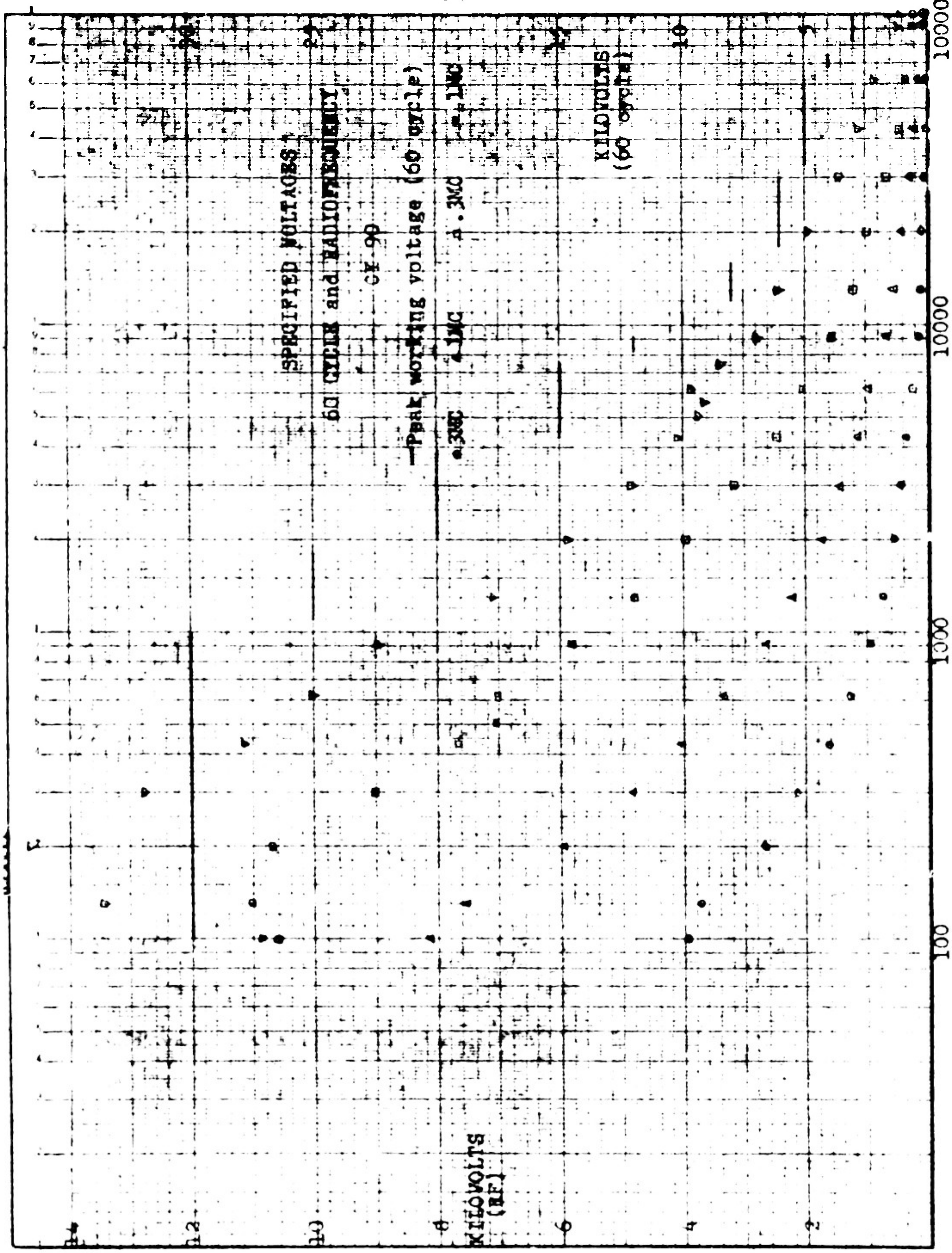

SPECIFIED VOLTAGES
60 CYCLE and RADIOFREQUENCY
CY 90
Peak working voltage (60 cycle)
3MC
1MC
.3MC
.1MC
KILOVOLTS (60 cycle)
KILOVOLTS (RF)
CAPACITANCE in MMFD
100
1000
10000
100000

FIGURE 7

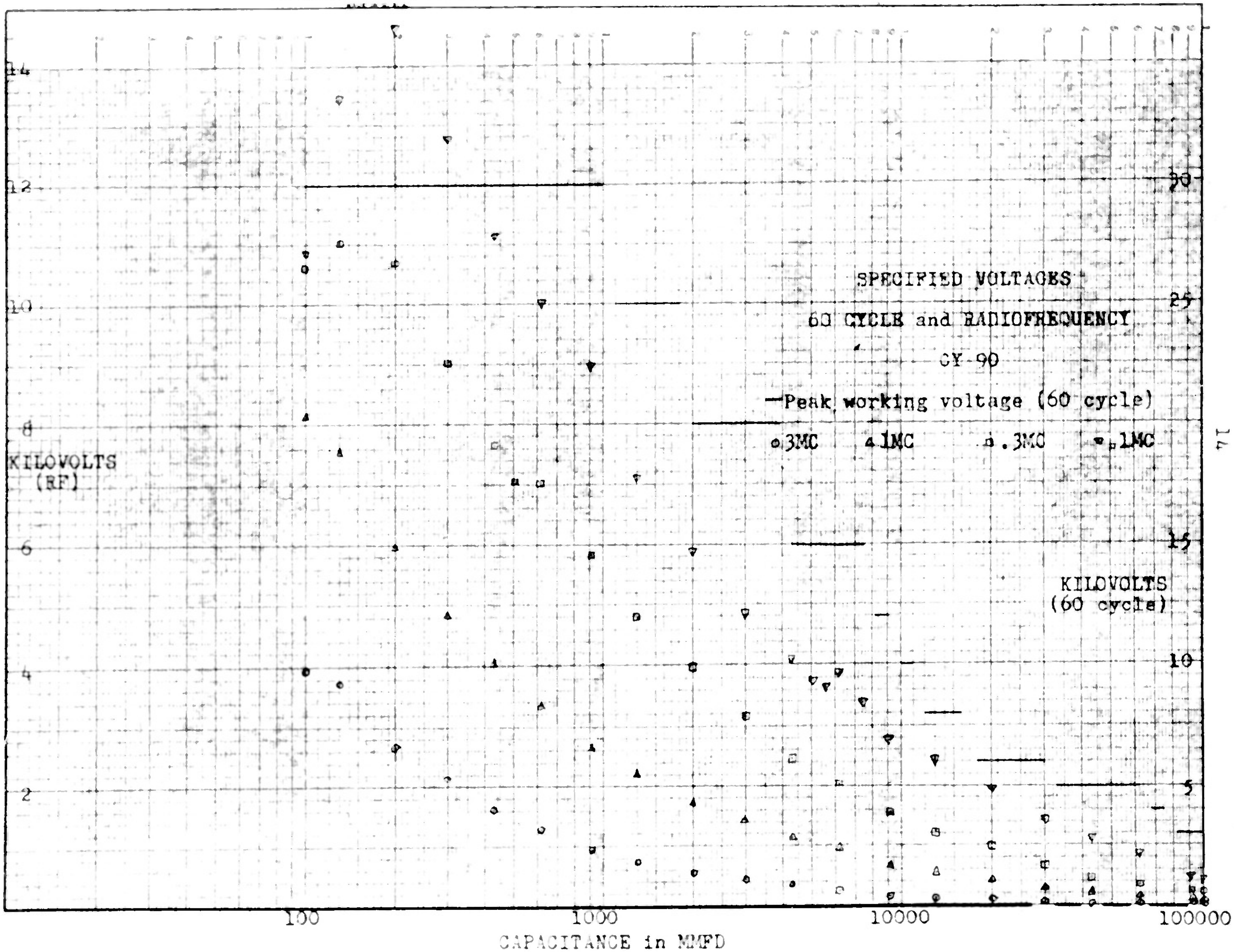

SPECIFIED VOLTAGES
60 CYCLE and RADIOFREQUENCY
CY-90
—Peak working voltage (60 cycle)
○3MC
△1MC
□.3MC
▽.1MC
KILOVOLTS (RF)
KILOVOLTS (60 cycle)
CAPACITANCE in MMFD
100
1000
10000
100000
2
4
6
8
10
12
14
5
10
15
20
25
30

FIGURE 7

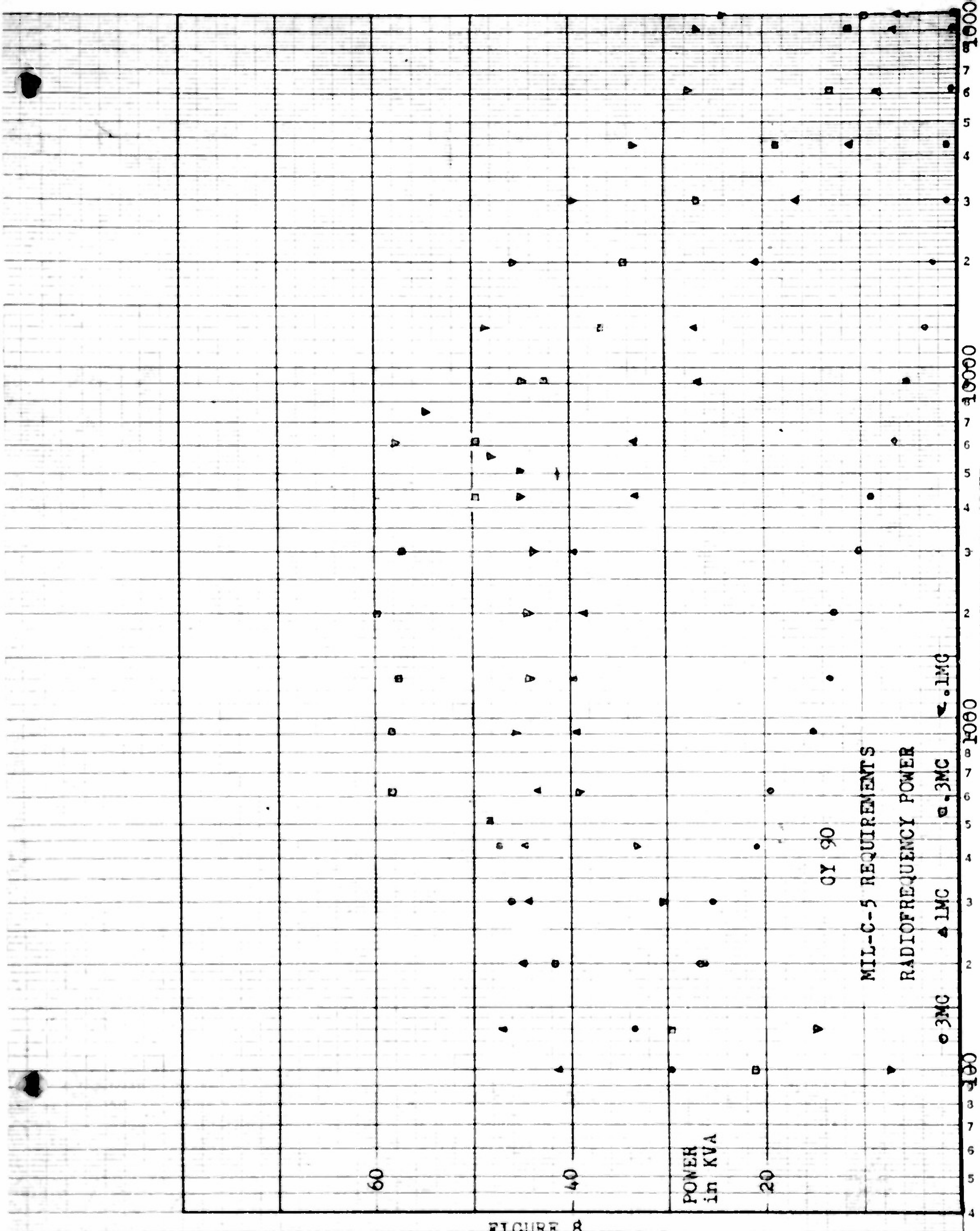

CAPACITANCE in MMFD
POWER in KVA
60
40
20
100
1000
10000
100000
MIL-C-5 REQUIREMENTS
RADIOFREQUENCY POWER
CY 90
.1MC
.3MC
1MC
3MC

FIGURE 8

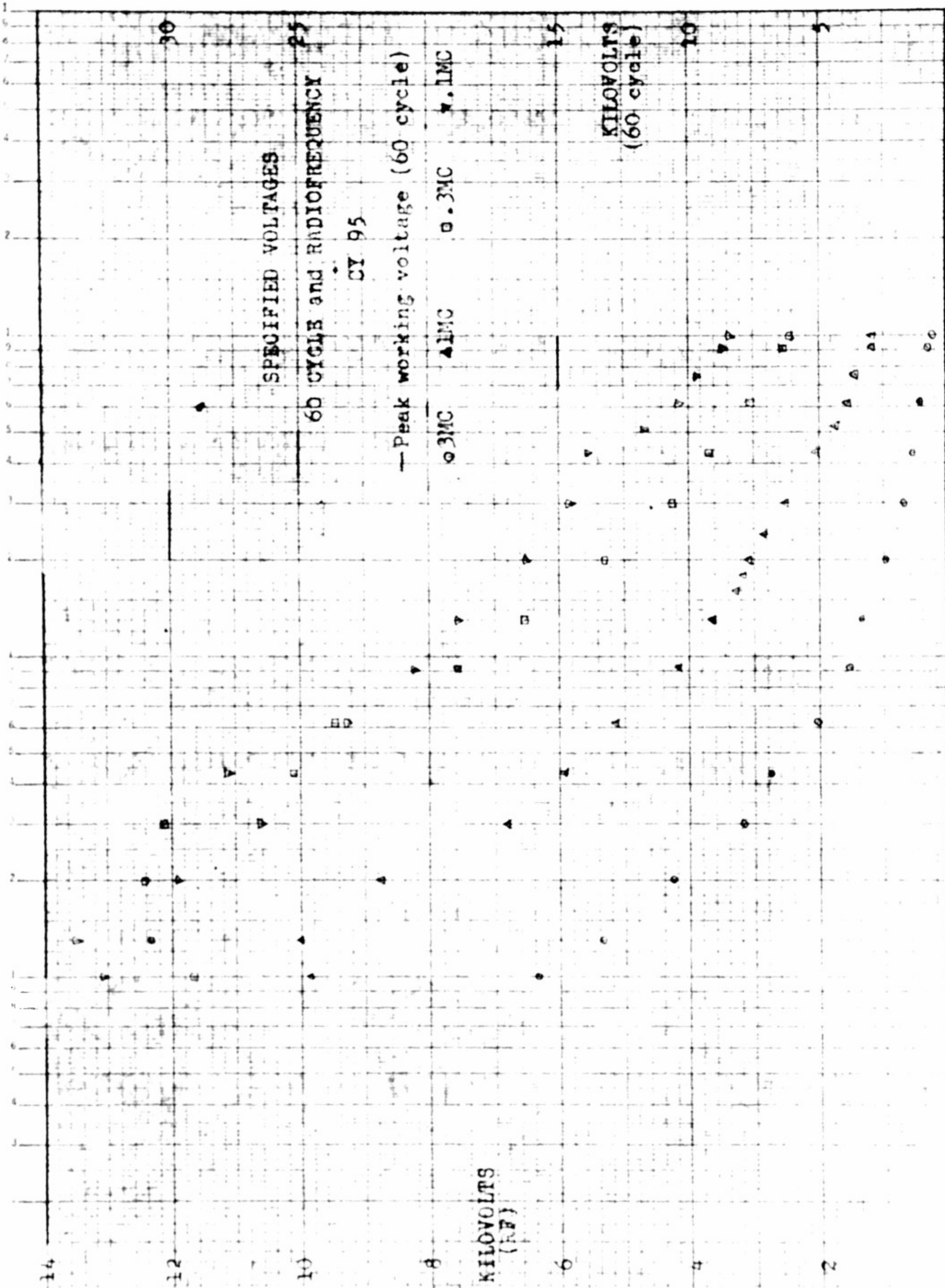

SPECIFIED VOLTAGES
60 CYCLE and RADIOFREQUENCY
CY 95
—Peak working voltage (60 cycle)
o 3MC
▲1MC
□ .3MC
▼.1MC
KILOVOLTS
(60 cycle)
KILOVOLTS
(RF)
CAPACITANCE in MMFD
100
1000
10000
5
10
15
25
30
2
4
6
8
10
12
14

FIGURE 9

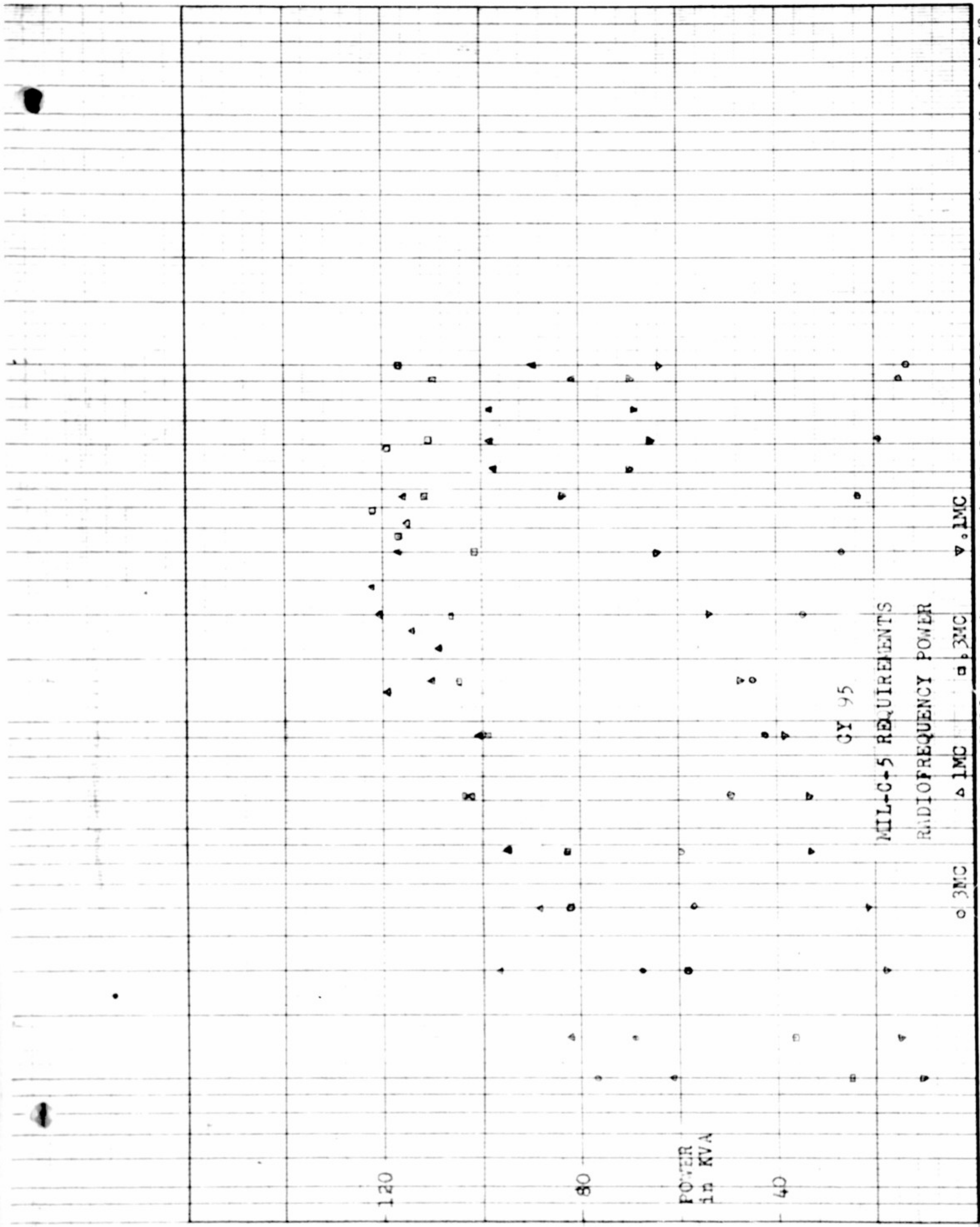

MIL-C-5 REQUIREMENTS
RADIOFREQUENCY POWER
CY 95
▽ .1MC
□ .3MC
△ 1MC
○ 3MC
CAPACITANCE in MMFD
POWER in KVA
120
80
40
100
1000
10000

FIGURE 10

In Figure 11 we have compared the general shape of the RF voltage curves at 0.3 megacycles for the 5 listed sizes CM75 through CM95, and Figure 12 the general shape of the reactive power curves at this frequency. It should be noted that these curves are highly idealized, the actual specified values are much more irregular. Table I shows the capacitance at which maximum power is dissipated (assuming a uniform power factor) for each case size, and this is compared to the surface area of the case. This latter ratio should be a measure of the temperature rise of the surface of the capacitor, under equilibrium conditions. It can be seen that part of the results of this contract may well become a more self-consistent and realistic set of requirements for radiofrequency operation for these sizes of capacitors.

Table I

Reactive Power of Transmitting Capacitors

Case Size	Maximum Reactive Power (volt amperes)	Capacitance at Maximum (mmfd)	Frequency (megacycles)	Surface Area (Sq.In.)	Power per Unit Area (KVA/in^2)
75	15800	1300	0.3	33.3	.475
80	22200	2400	0.3	57.0	.390
85	37800	5600	0.3	102.	.370
90	59500	3000	0.3	142.	.420
95	122500	5600	0.3	284.	.435

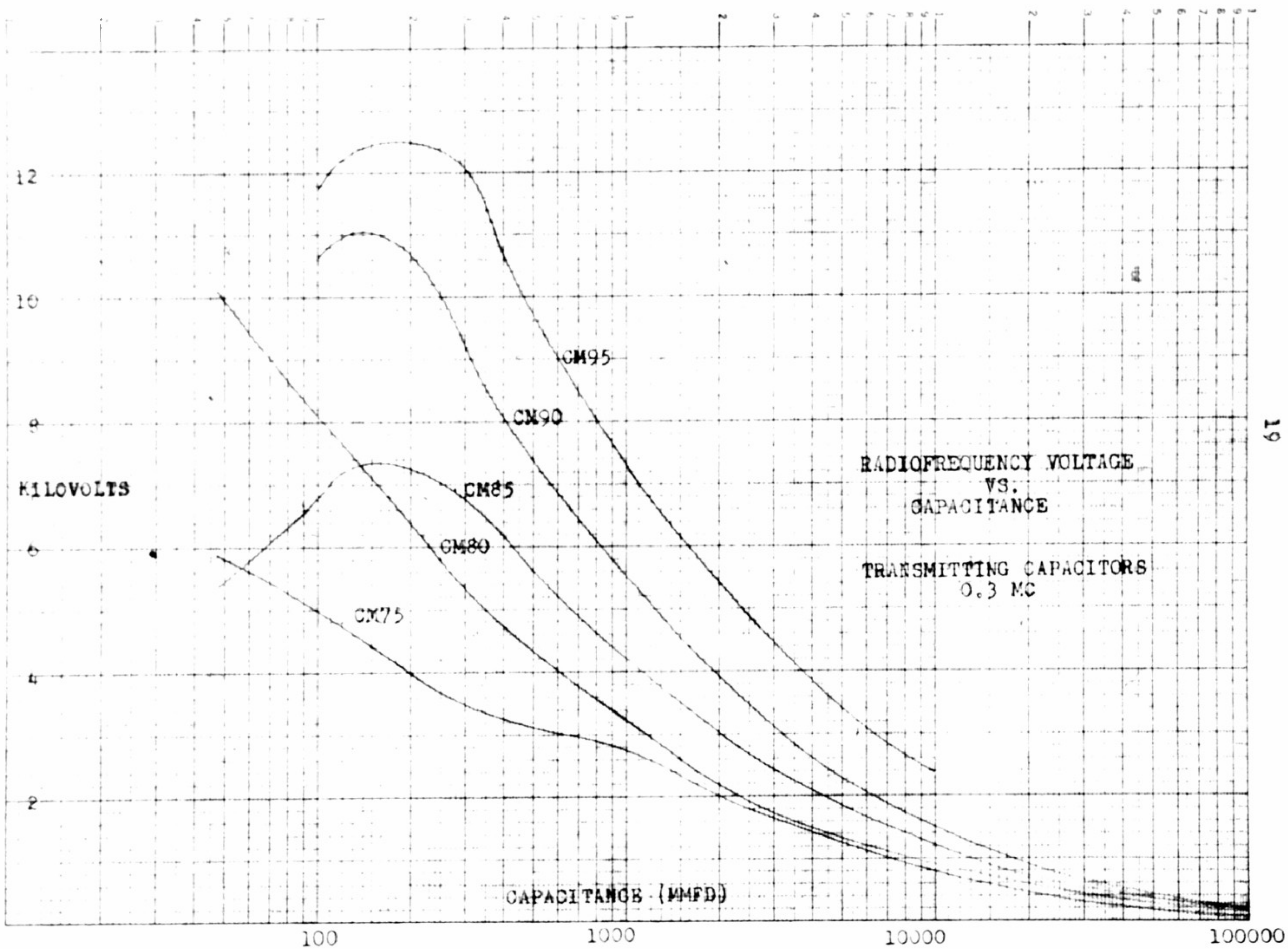

RADIOFREQUENCY VOLTAGE
VS.
CAPACITANCE
TRANSMITTING CAPACITORS
0.3 MC
KILOVOLTS
CAPACITANCE (MMFD)
CM95
CM90
CM85
CM80
CM75
12
10
8
6
4
2
100
1000
10000
100000

FIGURE 11

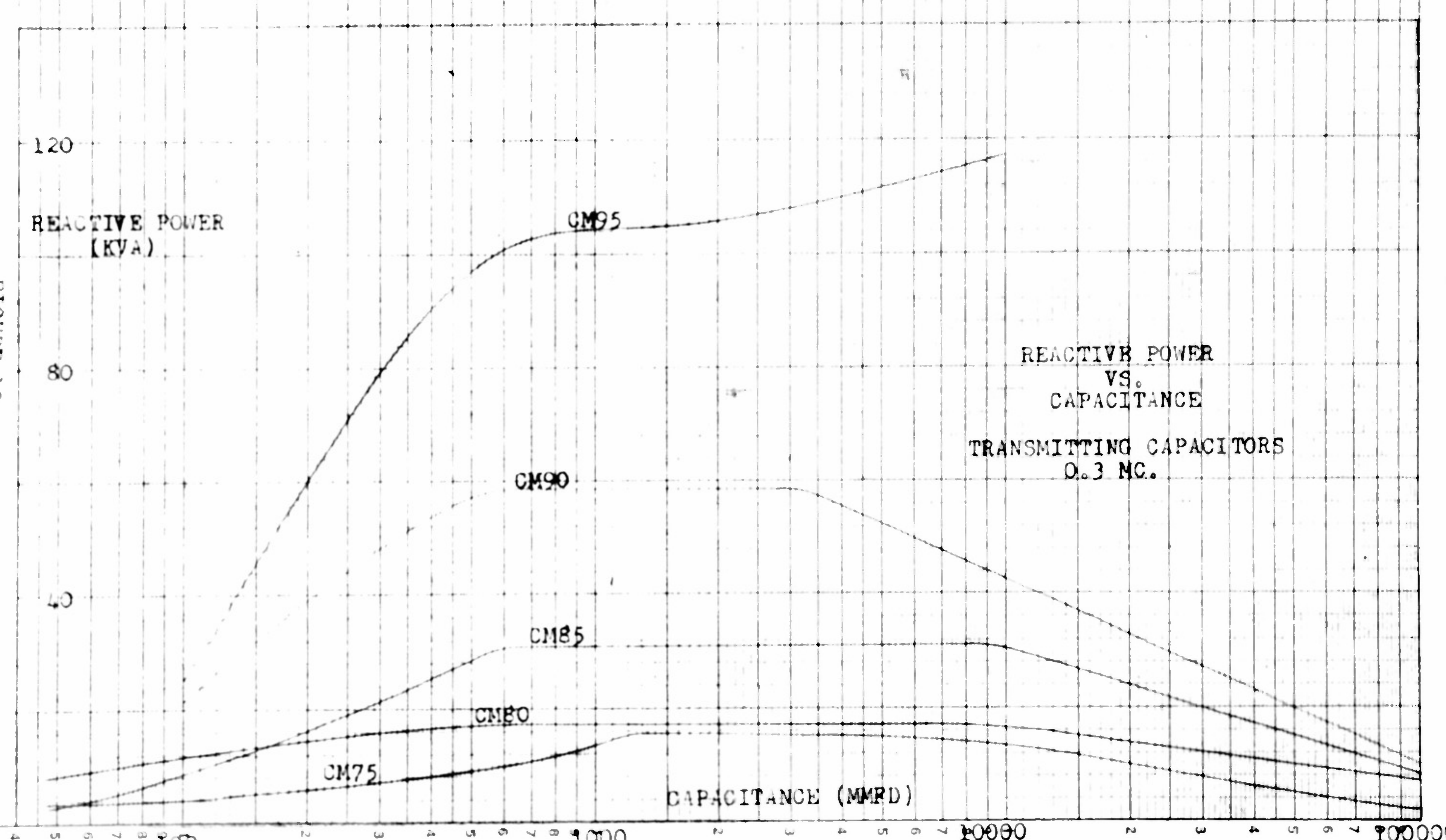

REACTIVR POWER
VS.
CAPACITANCE
TRANSMITTING CAPACITORS
0.3 MC.
REACTIVE POWER
(KVA)
120
80
40
CM95
CM90
CM85
CM80
CM75
CAPACITANCE (MMFD)
100
1000
10000
100000

FIGURE 12

Personnel

The following members of the Laboratory have spent the designated amount of time on this contract during this reporting period:

Sprague, L. G., Research Electrical Engineer	68 hours
Carlton, Mrs. K., Research Assistant	91 hours
Engler, Miss B., Junior Research Assistant	28 hours
Uncapher, Mrs. L., Junior Research Assistant	16 hours
Smith, G. P., Senior Research Associate	40 hours

Patents

The following patents, issued or pending, are considered to be directly applicable to this work:

Patent No. 2,405,529	G. P. Smith	August 6, 1946
Patent No. 2,422,466	D. H. Brown	June 17,1947
Patent No. 2,431,980	W. H. Armistead	December 2, 1947
Patent No. 2,526,703	G. P. Smith	October 24, 1950
Patent No. 2,526,704	G. J. Bair	October 24, 1950

Application No. 205,323 G. P. Smith Filed January 10, 1951

This application covers the use of cover glass, properly shaped for capacitor cover.

Application No. 227,966 G. P. Smith Filed May 24, 1951

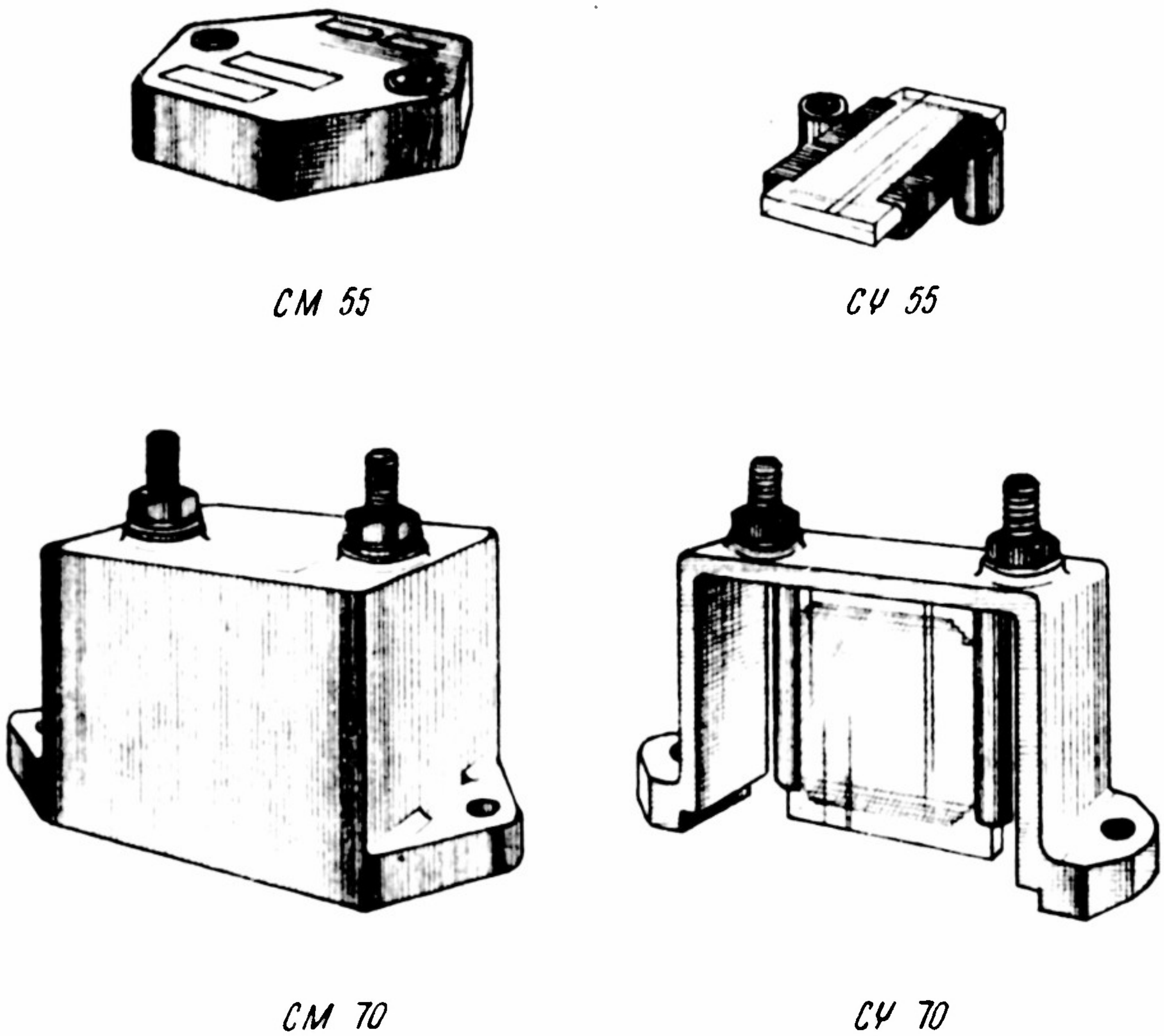
This application covers the use of an auxiliary water-repellent material to prevent penetration of moisture into the capacitors.

DETAIL FACTUAL DATA

1. Case and mounting of transmitting capacitors.

A very important advantage which a glass capacitor has is that the dielectrics and electrodes are intimately sealed together. It is obvious that capacitors fail because the localized dielectric stress, usually near the edges of the electrodes, becomes excessive for the dielectric. Homogeneous dielectrics such as glass follow the well-known square root law for the dependence of dielectric strength on thickness. It has been found possible to assemble and seal glass capacitors for high voltages which consist of n layers of thin dielectric with interpolated uniformly spaced equipotential plates, rather than one layer n times as thick. These equipotential plates force the field to remain much more nearly normal to the plates, and reduce the gradients within the dielectric so that the failure voltage is very nearly linear with total thickness. The behavior is much like that of the usual construction of n capacitors in series. For voltages such that several layers of a given thickness are necessary, this greatly reduces the required total thickness of dielectric, and therefore the size of the capacitor for a given rating.

This kind of construction was developed for capacitors of size designation 55 by Corning Glass Works during 1944-1947, and several thousand of them were supplied on order to the Navy Department, Bureau of Ships. Some work has also been done on the development of sizes 65 and 70 using this technique. Figure 13 shows the comparison of the glass capacitors made in this manner with the mica capacitors they will replace. They are seen to be physically interchangeable with the bakelite-housed capacitor. Without this requirement further economies in size and weight might become possible. A few experimental capacitors have been made in the general form of the cylindrical capacitors covered by the present contract, by using glass capacitor components containing a larger number of equipotential electrodes between the active conductors. Figure 14 shows a sketch of such an assembly, compared to the conventional capacitor housed in a ceramic cylinder. Again physical interchangeability has been maintained, but it is seen that the weight has been markedly reduced, and because of the much more efficient cooling of the capacitor proper, the power might well be increased. Figure 15 displays a comparison between the rate and amount of temperature rise of a standard mica CM80 capacitor and a glass capacitor made as sketched in Figure 14. The over-all height of the glass capacitor was 2-3/8"; of the mica capacitor, 3". Temperature was measured by a thermocouple attached directly to the surface. An important advantage of this construction is seen to be the rate at which equilibrium is reached. If the length of the glass capacitors had been increased so that an over-all height of 3" had been required, the equilibrium temperature would have been correspondingly reduced.



POSSIBLE GLASS CAPACITORS COMPARED
TO PRESENT DESIGN

FIGURE 13

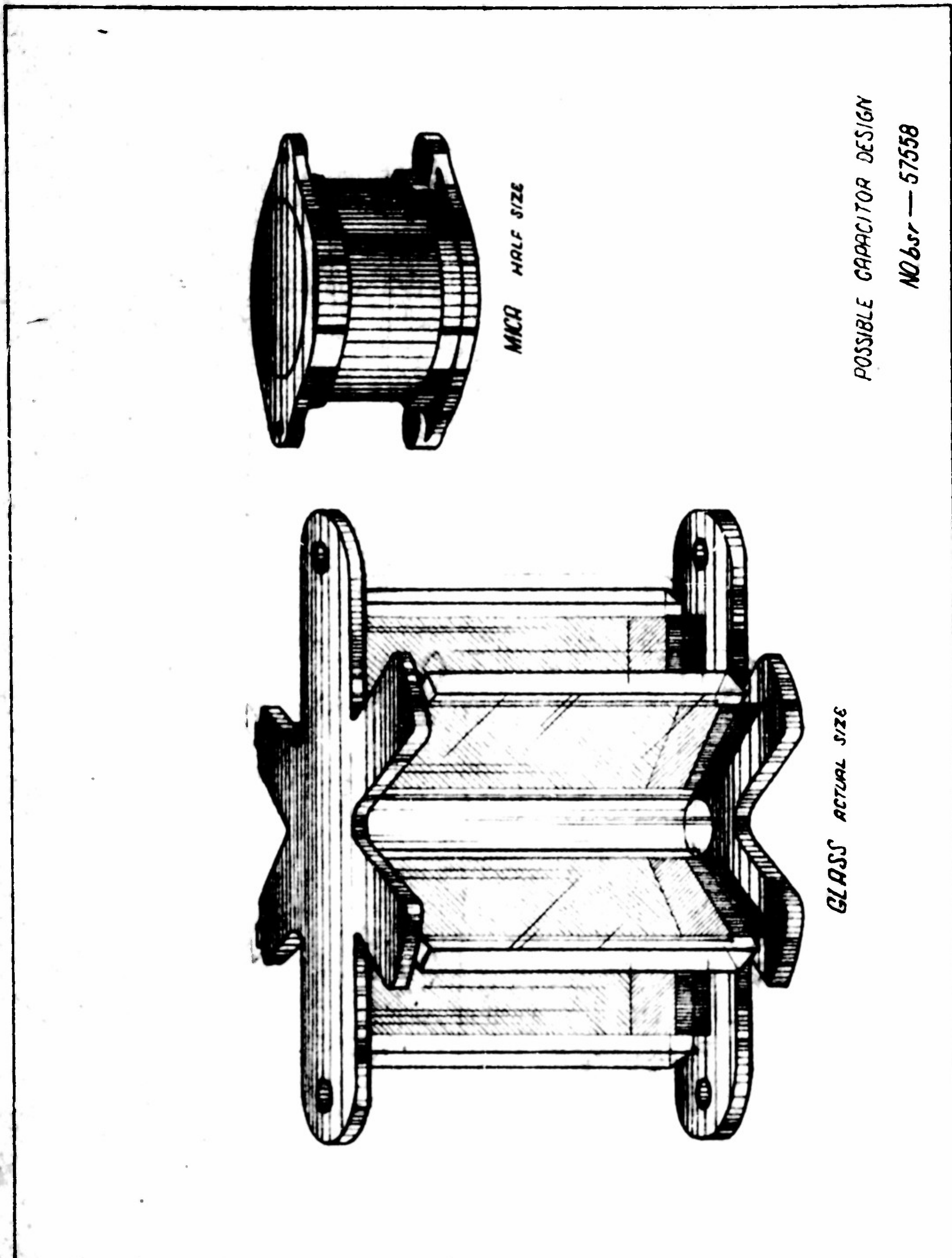

POSSIBLE CAPACITOR DESIGN
NObsr — 57558
MICA HALF SIZE
GLASS ACTUAL SIZE

FIGURE 14

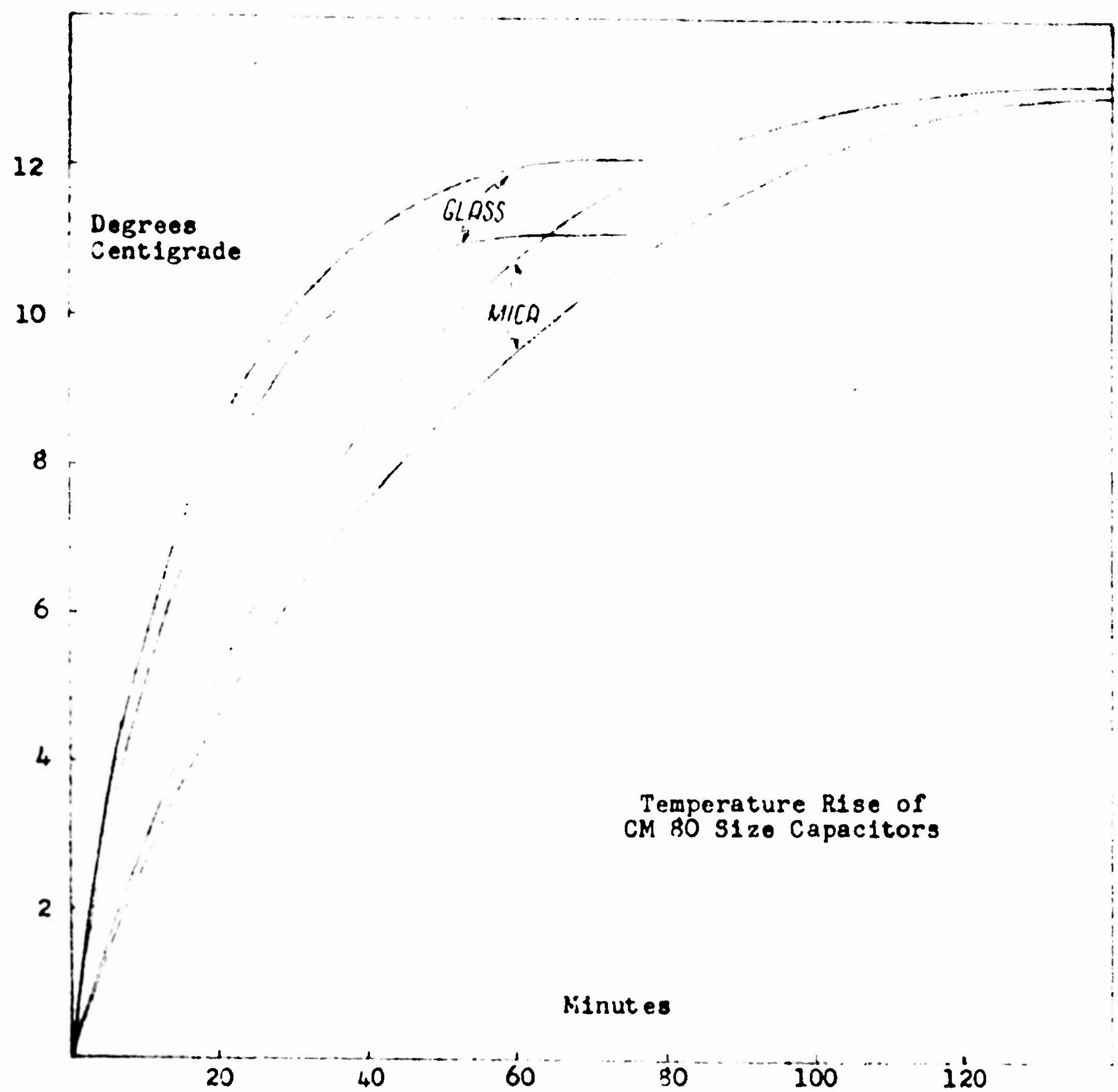

12
10
8
6
4
2
Degrees
Centigrade
GLASS
MICA
Temperature Rise of
CM 80 Size Capacitors
Minutes
20
40
60
80
100
120

FIGURE 15

2. Electrical design of capacitor components.

Much of the work on electrical design so far completed on Contract DA36-039-sc-15509 cited above is directly applicable to this work, and reference is made to the first three Quarterly Reports of the work under that contract for a complete discussion of the results obtained. They will be briefly summarized in this and the following section.

Life tests at 85°C with both DC and 60 cycle AC voltages have shown that capacitors with glass dielectric may be safely operated at relatively high voltages. A convenient thickness of glass dielectric is .0027"; capacitors of relatively high capacitance have survived life tests for more than 5000 hours at 1875 volts DC, or 875 volts AC, at 85°-95°C, with no failures. These therefore may not be the upper limits of voltage rating for this thickness of dielectric. Thinner dielectrics (.0018" and .0013") have given results during the course of life testing under the above contract which are poorer than expected and are not yet entirely explained, and dielectric and strength tests are continuing. Some work is now being done on the replacement of the aluminum foil electrodes by metallized or evaporated coatings, to reduce the mechanical stress introduced by the glass-to-metal seal between the dielectric layers and the foils of different thermal expansion coefficients.

A good operating criterion of a capacitor or a capacitor component is the lowest voltage at which corona occurs. This is even more slowly dependent on the thickness of the dielectric than the breakdown voltage. Measurements during the course of the cited contract have shown that the onset of corona is at about 400 volts for capacitors made with .0027" thick glass, both at 60 cycles and radiofrequencies. Thus the glass capacitor can operate at voltages far in excess of its corona voltage without serious effect on its life. A search has been made for a quick and reliable electrical method of determining the onset of corona. Observation of this as noise by a pickup coil or plate near the capacitor under test is a promising method, but has not yet been made trouble-free.

The corona discharge occurs first at small bubbles or voids between the layers of the high dielectric constant glass dielectric at the edges of the relatively thick (.00017") foils. Other gases or vapors might be purposely introduced into the capacitor to reduce the corona current or inhibit the corona discharge. Attempts to do this with SO_2 gave negative results. Experiments to introduce a glass which is much softer than the code 8871 dielectric glass, so that it would flow around the edges of the foils during the sealing process and fill this space have so far been fruitless in most instances, although an occasional sample has shown a much higher voltage than the others. This work is also being continued.

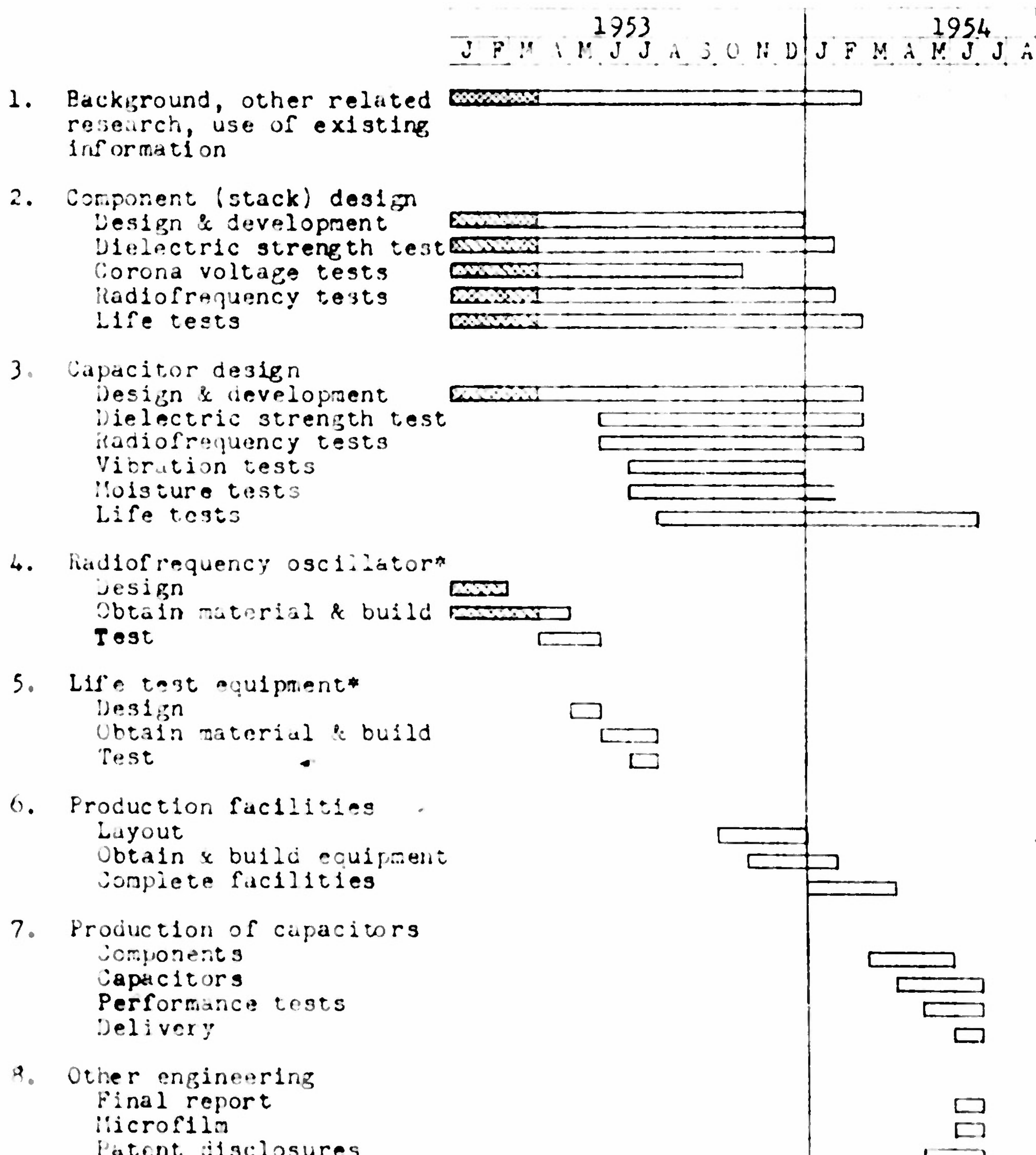
3. Construction of terminals of capacitors.

Besides the usual requirements placed on the materials for capacitor terminals by the electrical and environmental conditions under which the capacitor will operate, there is an additional severe one imposed by the fact that they must be attached to the glass. The type of terminals shown in Figure 13 are soldered to thin strips of silver sealed to the glass surface. A satisfactory redesign of this has been evolved with the terminal embedded in the mass of the glass and held there mechanically but prevented from sealing to the glass by a overwrapping of thin metal. These metals are aluminum; the exposed part of the terminal has been cased with a solderable metal, or supersonically tinned. This terminal which is relatively simple but mechanically rugged, should be adaptable to capacitors as described in Figure 14 above.

CORNING GLASS WORKS

PROJECT PERFORMANCE and SCHEDULE

Contract NObsr-57558 April, 1953



*Necessary for performance tests, but to be supplied by Corning Glass Works.

FIGURE 16

PROGRAM FOR NEXT INTERVAL

The program of work to be completed for the next reporting interval is diagrammatically laid out in the foregoing schedule, Figure 16. Most of it will be a continuation of work already started, and will be directly aimed at determining the optimum electrical and mechanical design of the integral sealed capacitor stacks, for high voltage capacitors. The usual tests to evaluate the performance of these stacks will be continued and amplified. Parallel to this, and with it constantly in mind, will be the design of the completed capacitor, terminals, and housing if necessary. A radiofrequency oscillator, which is now being built by Corning for measurements on the completed capacitors, will be finished and tested. Life test equipment, also to be supplied by Corning, will be designed, constructed, and placed in operation. Much of this work will be closely related to, but will be in addition to, work on the medium power capacitors, sizes 55 through 70.

RADIOFREQUENCY OSCILLATOR

The most critical measure of the performance of these capacitors is their temperature rise, i. e., power factor, at rated radiofrequency current. For such measurements a radiofrequency oscillator has been designed and is being built by Corning Glass Works. It is believed to be of general interest, and for reference the circuit diagrams follow.

The RF amplifier, which is a pair of triodes operating in push-pull Class C, is excited by a crystal-controlled driver-amplifier stage for frequency stability. A maximum plate voltage of 4.5 KV will be available from the variac-controlled full wave power supply, which will be sufficient for radiofrequency measurements at maximum reactive power (122KVA) for the largest case size.

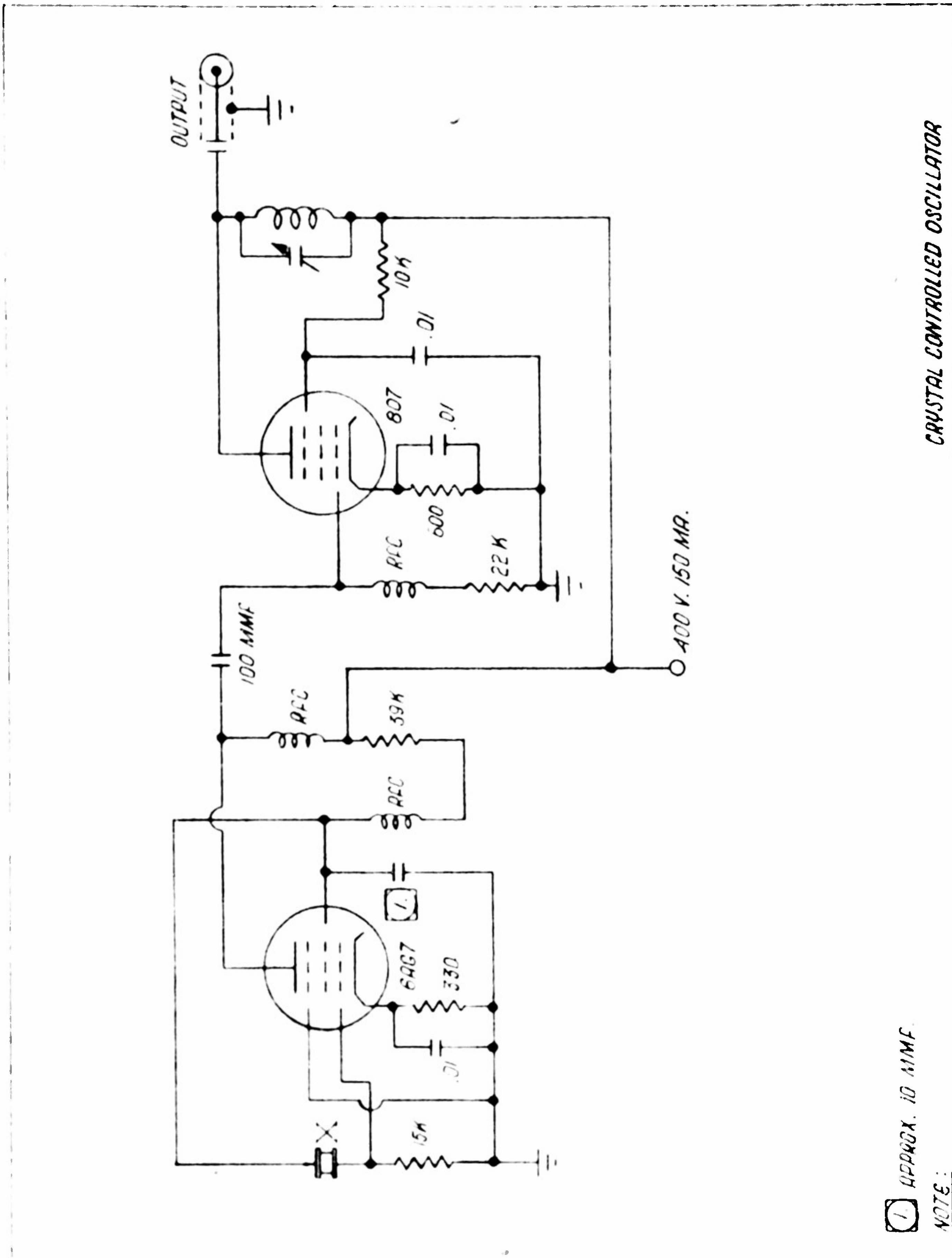
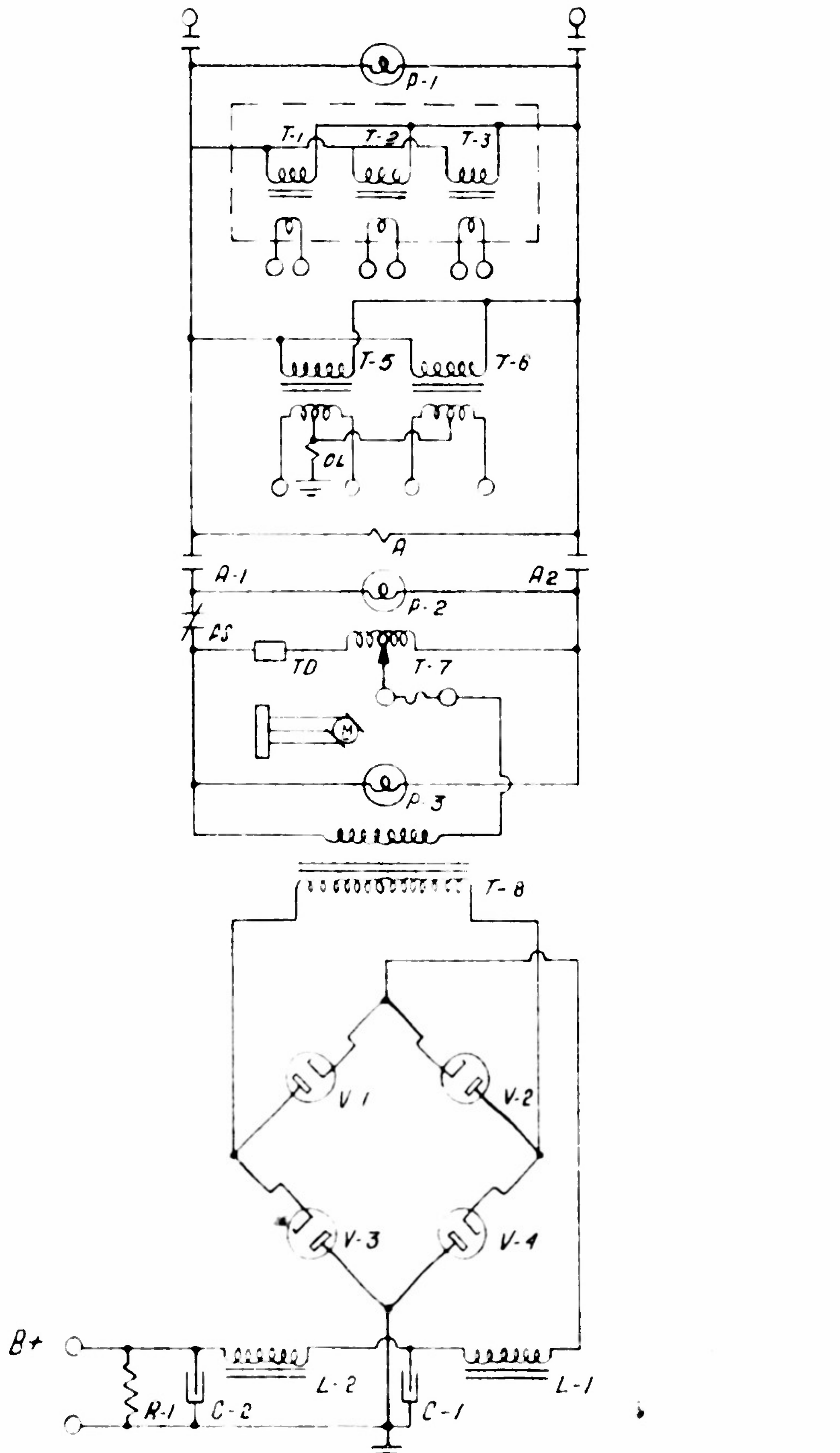

OUTPUT
10K
.01
807
.01
600
RFC
22K
400 V. 150 MA.
100 MMF
RFC
39K
RFC
1.
6AG7
330
.01
15K
X
NOTE:
1. APPROX. 10 MMF.
CRYSTAL CONTROLLED OSCILLATOR

FIGURE 17



POWER SUPPLY – R.F. AMPLIFIER

FIGURE 18

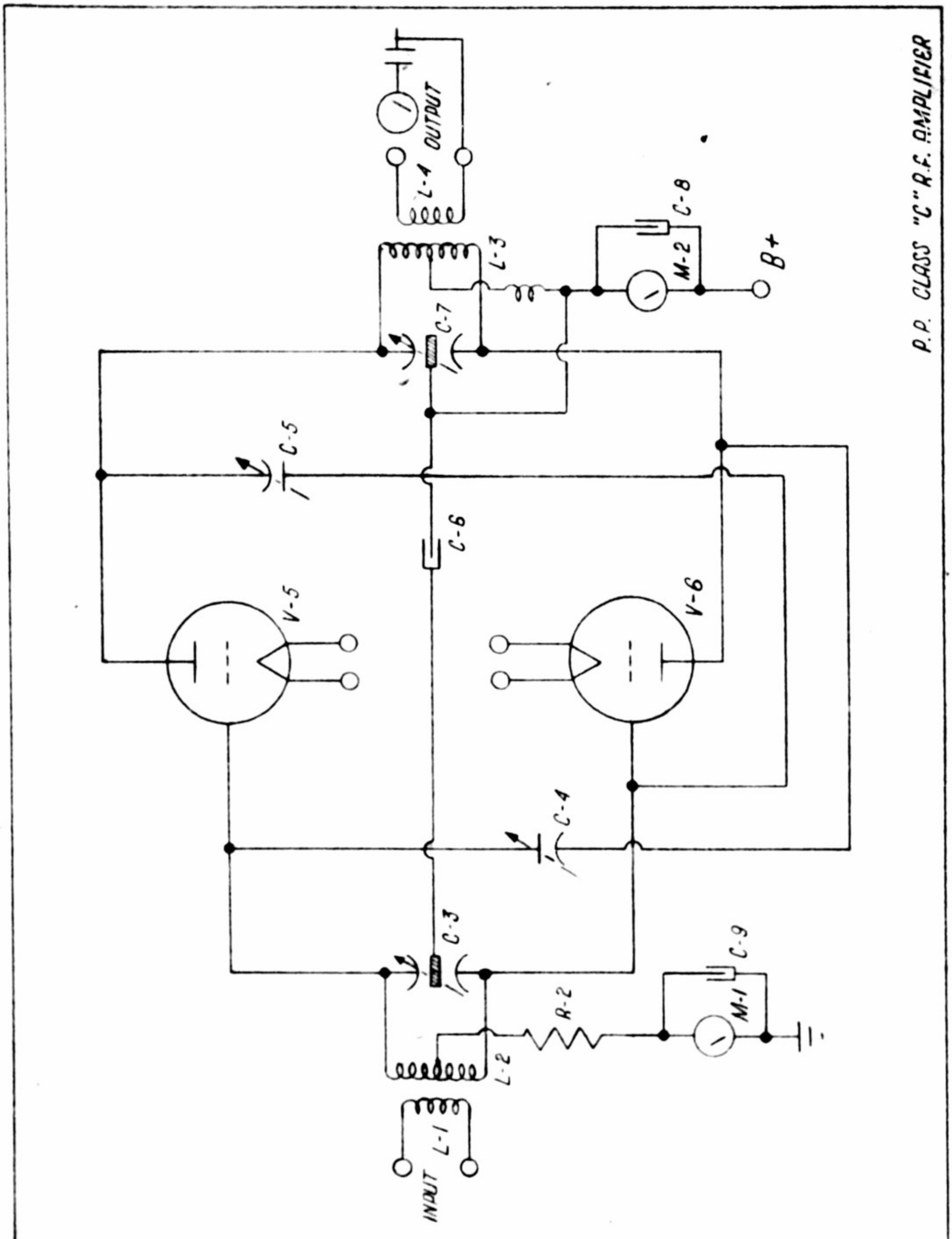

P.P. CLASS "C" R.F. AMPLIFIER
OUTPUT
INPUT
L-1
L-2
L-3
L-4
C-3
C-4
C-5
C-6
C-7
C-8
C-9
V-5
V-6
R-2
M-1
M-2
B+

FIGURE 19